Linking Energy Efficiency and Indoor Environmental Quality to Reduce Children's Exposure to Volatile Organic Compounds **Study Design, Recruitment and Monitoring Methodology for Demonstration Project with New Relocatable Classrooms at Northern California Public Schools**

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INTRODUCTION
LBNL/DEG/CEC STUDY

Pilot demonstration project evaluating energy efficient heating, ventilation and air conditioning (HVAC) system technologies and interior materials in prototype relocatable classrooms (RCs).

RCs are standard configuration, 24’ W x 40’ L, composed of two symmetric, prefabricated modules.

GOAL

OVERALL GOAL

Demonstrate designs with simultaneous energy efficiency gains and good indoor environmental quality

Improved indoor environmental quality (IEQ) =

- Fresh outdoor air
- Particle filtration
- Continuous ventilation
- Dilution of pollutant concentrations
- Source reduction, lower emissions of toxic or odorous VOCs
- Temperature control with moderate relative humidity

CONTEXT

Current Situation in CA

- Federal and CA policy initiatives to reduce public school class size, K-3 student-to-teacher ratio of 20 since 1997-98
- Limited resources for capital projects, modernization and maintenance
- Health effects of unknown etiology reported, possibly due to use of RCs
- Mechanical HVAC systems may be improperly operated or poorly installed and maintained, including removable filters
- CA has experienced electricity crisis, high gas prices

CONTEXT

Relevant Regulations, Guidelines, Codes

- Proposition 65, toxic air contaminants
- CA Air Resources Board, IAQ Guidelines:
  - No.1, H2CO
  - No. 3, chlorinated compounds/solvents

- DGS/DSA-OPSC RC specifications-- materials, design, HVAC, siting
- Recent CA legislation-- IPM not pesticides at schools, fund a state PCS

- ASHRAE 55-1992, thermal comfort
- ASHRAE 62-1999, outdoor air ventilation rates for, and CO_2 levels in, commercial buildings

- CA: Code of Regulations, Title 24, energy efficiency

METHODOLOGY

RECRUIT PARTICIPANTS, COLLABORATORS

REQUIREMENTS

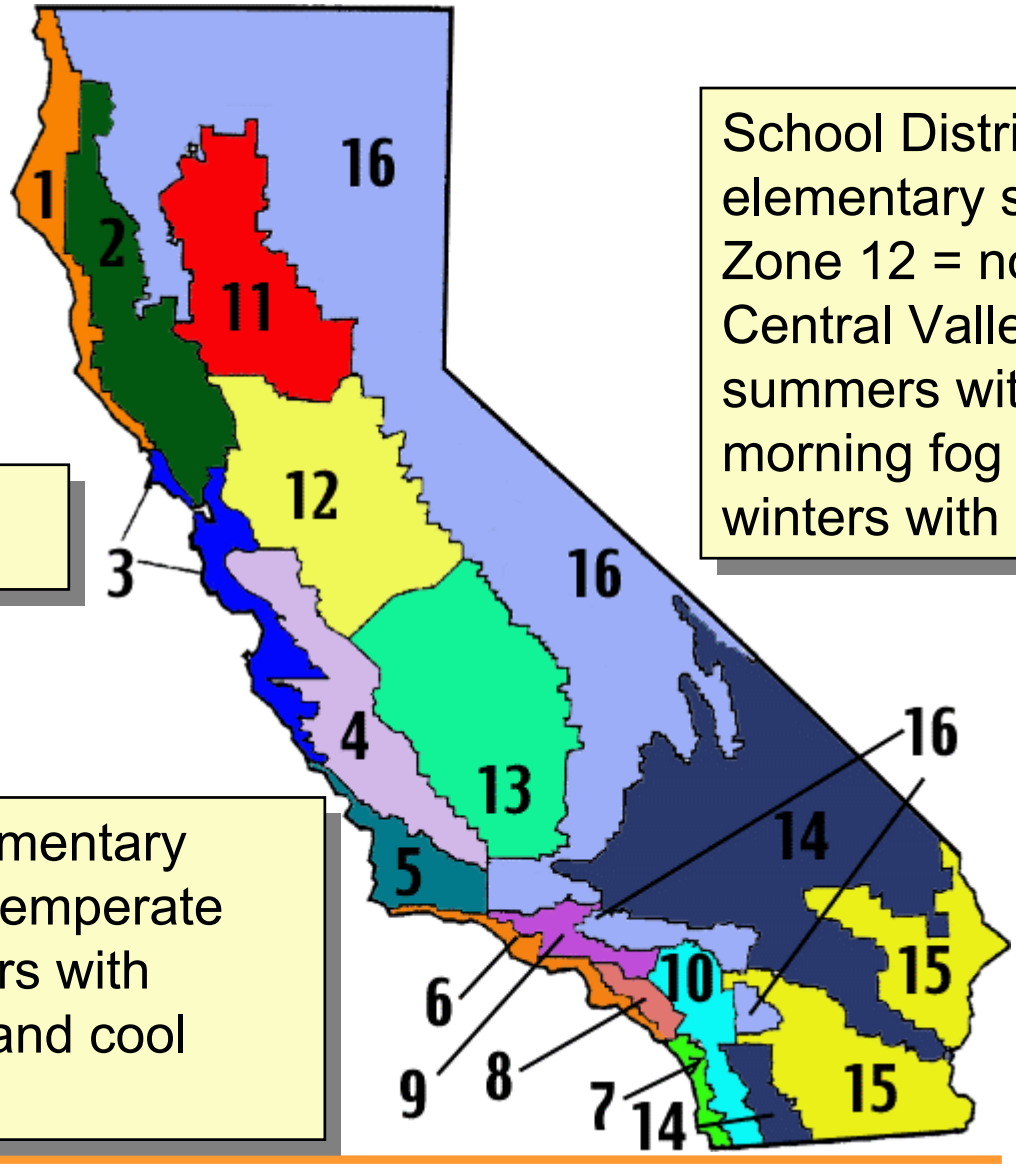
- One CA RC manufacturer and two school districts (SD) in two distinct Northern CA climate zones, with one elementary school in each participating SD receiving two RCs.

PROCESS

- RC manufacturers; 5 --> 1
- SD; 12 --> 3 --> 2
- Selection of elementary schools
- Manufacturers/suppliers of roof coatings and alternative interior r

LOCATIONS OF STUDY

NORTHERN CA CLIMATE ZONES



School District B's elementary school is in Zone 12 = northern Central Valley, hot dry summers with possible morning fog and cold winters with rain.

The RC manufacturer is located in Zone 12.

School District A's elementary school is in Zone 4 = temperate climate, warm summers with possible morning fog and cool winters with rain.

METHODOLOGY
STUDY DESIGN

Case-crossover design: each RC serves as own control.

- Each of the two modules of an RC have a wall-mount HVAC system
- Comply with CA construction regulations, fire codes, and SD architect

- The two HVAC systems:

1.) conventional electric heat pump system

2.) advanced indirect/direct evaporative cooling, gas-fired hydronic heating.

- Two RCs sited side-by-side at each school site.
- Different HVAC systems operate on alternate weeks.

HVAC SYSTEMS

Case-crossover design

HVAC SYSTEMS

Standard:

Bard 10 SEER, 3.5 ton, wall-mount,

1” replaceable filter, 10-20% dust spot efficiency

1400-1500 ft^3/min supply with 25% outdoor air ventilation

Advanced:

Indirect-direct evaporative cooler (IDEC) with instantaneous gas-fired water heater

100% outdoor air ventilation

Novel air filtration system, 65% dust spot efficiency

315-1540 ft^3/min as a function of occupancy and HVAC mode, i.e. heat, AC, or fan

Study's Advanced HVAC System

Major Components and Mounting Configuration

LBNL advanced HVAC system for public school RCs: IDEC and filtration (R), instantaneous natural gas-fired hydronic heater (L), mounted on a module back wall. IDEC control thermostat, in lock box.

INTERIOR MATERIALS

STANDARD MATERIALS

In one of two classrooms per school
Used by collaborating manufacturer, to state specifications
Eight categories evaluated

ALTERNATIVE MATERIALS

In other of two classrooms per school
Researched options for four of eight categories
Tested available, affordable, easily maintained, potentially beneficial options
Environmental chamber/controlled environment conditioning period,
followed by an air sample for VOCs and aldehydes

Result = recommended alternatives in three categories

Ceiling panels
Teflon-coated vinyl-covered tackable wall panels
Carpet & adhesive system, SD B only

METHODOLOGY

IEQ & ENERGY MONITORING, SCHEDULE

- In each of the cooling and heating seasons, 4-5 weeks of data under each of the two HVAC operating modes will be obtained.

- Visit each school once a week:
  - Avoid possible weekend build-up of pollutants in unoccupied, unventilated and unconditioned RCs
  - Account for logistics and school holidays

Thus, integrated school day measurements are conducted on 2-3 Tuesdays/Wednesdays and 2-3 Thursdays in each season under each HVAC operating mode.

TARGET COMPOUNDS AND PARAMETERS MONITORED IN THIS STUDY

IEQ and ENERGY USE MONITORING

Particle counts: continuous, 0.3-10 μm in 6 bins, indoor & outdoor

CO_2: continuous, indoor & outdoor

VOCs, **formaldehyde**, **acetaldehyde**: one 7-8 hour sample per week, indoor & outdoor

T°: 11 indoor locations, continuous

RH%: 5 indoor locations, continuous

A-weighted sound levels: continuous

Weather station outside RCs: **outdoor T°**, **RH%**, **wind speed** & **direction**

Electricity use: HVAC systems, lights, computers

Natural gas use: advanced HVAC system

METHODOLOGY

IEQ & ENERGY MONITORING

Environmental monitoring data are logged continuously by a computer central data acquisition system in a LBNL-designed indoor cabinet, located above teacher storage space and out of a student's reach.

METHODOLOGY

IEQ & ENERGY MONITORING (continued)

The sound level meter, and T° and RH% sensors, are located on a mobile suspended 1.5’ below the ceiling and 7’ from the floor, also out of a student’s reach.

METHODOLOGY

IEQ & ENERGY MONITORING (continued)

- Most parameters monitored continuously for 7-9 weeks in each of the cooling (fall 2001) and heating (winter 2002) seasons
- 7-8 hour integrated concentration measurements of volatile organic compounds (VOCs) and target aldehydes once a week.
- An ASHRAE-based thermal comfort assessment with a specially designed cart, is conducted once a week during school hours for students and/or teachers

METHODOLOGY
DATA AND SAMPLE ANALYSES

- Integrated school day samples, stored and transported to and from LBNL and school sites in coolers, will be analyzed at LBNL:
  - thermal desorption followed by gas chromatography/mass spectroscopy for the VOCs
  - extraction with acetonitrile, followed by high performance liquid chromatography with UV detection for formaldehyde and acetaldehyde

QUALITATIVE DATA COLLECTION

TECHNICIAN-ADMINISTERED CHECKLISTS

Four technician-administered checklists and surveys developed and used:

- **Classroom Checklist**, indoor physical environment attributes e.g. number and state of windows, doors; odors; energy use (lights, computers).

- **Technician Walk-Through assessment;** potential sources of measured gas and particle phase indoor air pollutants, and biological contaminants.

- **Classroom Attendance/Temporary Absenteeism** inventory; combine with CO_2 data to characterize occupancy and examine ventilation rates.

- **Teacher and Student Clothing Checklist**; use with thermal comfort cart (TC) data (T°, RH%, air velocity) to assess, by HVAC, provision of TC.

PROJECT PROGRESS
(as of 11/2/01)

- Cooling season monitoring in fall 2001 completed
- CO_2 decays and emission factor calculations completed
- Chemical analyses on, and associated calculations for, fall 2001 cooling season VOC and aldehyde-DNPH samples completed
- SAMPLE OF REPRESENTATIVE DATA GRAPH
  - weekly CO_2 profile, advanced IDEC-hydronic heating system